International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 3, Jun 2019, 525-532

THE PERFORMANCE ANALYSIS OF A REFINING SYSTEM BY USING MARKOV PROCESS

AMAN[1], ABHISHEK KUMAR[2], V. K. MAHNA[3] & RAJIV KHANDUJA[4]

[1]Research Scholar, Department of Mechanical Engineering,
Manav Rachna International Institute of Research and Studies, Faridabad, Haryana, India
[2]Associate Professor, Manav Rachna International Institute of Research and Studies,
Faridabad, Haryana, India
[3]Pro-Vice Chancellor and Professor, Manav Rachna University, Faridabad, Haryana, India
[4]Professor, Jawaharlal Nehru Government Engineering College, Sunder Nagar, Himachal Pradesh, India

ABSTRACT

The availability analysis of the refining system in a sugar plant is explored in the present paper. There are various subsystems which are complex in nature and are repairable. In a sugar plant, there is (i) feeding system (ii) refining system (iii) evaporation system (iv)crystallization system. one of the important systems is refining system. It has (i) clarifier filter units, (ii)Sulphonation units (iii) heating units. If anyone of these units fails, overall refining system fails.

The mathematical modelling is used for analyzing the availability. The differential equations of first order are developed. Normalizing conditions are applied to find out steady state availability and the equations are resolved. This result is helpful for analyzing availability and for determining maintenance approaches of the sugar industry.

KEYWORDS: Steady State Availability, Refining System, Markov Process Maintenance Strategy, & Mathematical Modelling

Received: Mar 02, 2019; **Accepted:** Mar 22, 2019; **Published:** Apr 26, 2019; **Paper Id.:** IJMPERDJUN201956

Original Article

1. INTRODUCTION

Sugar cane is the raw material mainly handed down for production of sugar. It is necessary to run system failure free, interminable, efficiently and full amplitude to get maximum production. In actual situations, the operative units get random failures.

In this analysis availability is achieved. This real system is modelled mathematically and analysis is done in the actual conditions. The different differential equations are made and solved using normalizing conditions, for analyzing the overall availability.

2. REFINING SYSTEM DESCRIPTION

The sub-systems in the refining system are, (a) filter unit has units in the series and one's failure will lead to the failure of the full system (b)clarifier sub-system has units in the series and the one's failure will lead to failure of the full system. (c) Sulphonation sub-system has units in the parallel; the failure reduces the efficiency and capacity in the sugar industry.

3. ASSUMPTIONS

- Failure and Repair rates remain independent/ constant.
- The repaired units are like a new one.
- Services include renewal and service.
- Repair starts without any delay.

4. NOTATIONS

Notations: , , represents full capacity, reduced capacity and failed state.

The effective states of the subsystems are A, B, C, D and failed states of sub-systems A, B, C, D are i, j, k, l. The repair rates of the sub-system A, B, C, D are α_I, α_J, α_K, α_L. The failure rates of the sub- system A, B, C, D are β_I, β_J, β_K, β_L. The representation is as follows.

1-Full working/Operative state

2,3,4,5,6-Reduced state,

7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23-Failed state.

$P_s(t)$ - System's probability at time t in state s.

5. MODELLING BY USING MARKOV PROCESS

The modeling is done by contemplating that time used in repair and working in full capacity is exponentially distributed.

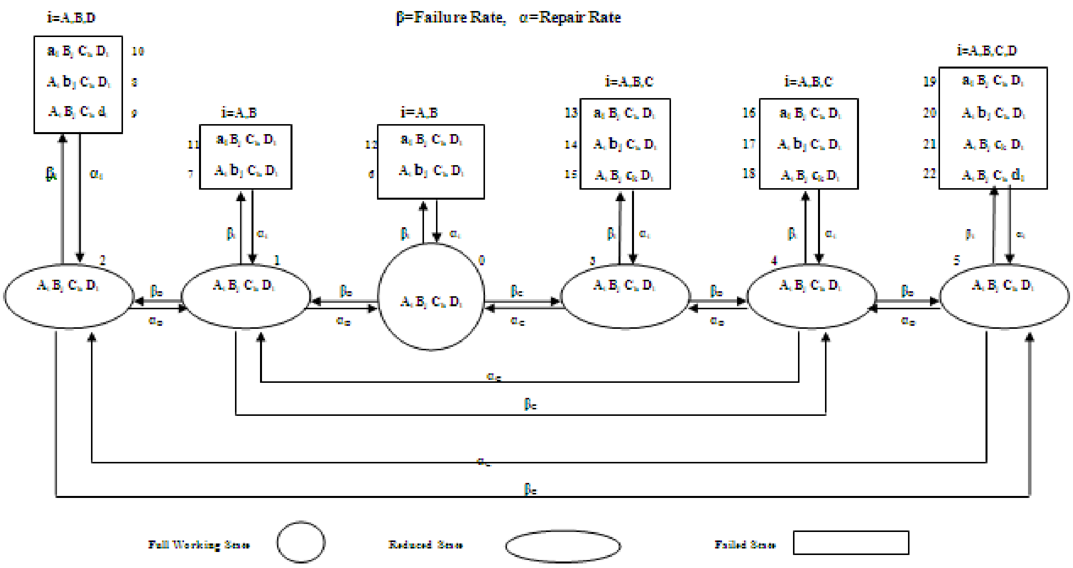

Figure 1: Transition Diagram of Refining System

The associated differential equations are given as

$$P_1{}'(t) + \sum \beta_I P_1(t) = \sum \alpha_J P_K(t) \tag{1}$$

$P_2\ '(t) + \sum (\beta_I+\alpha_L)P_2(t) =\sum \alpha_J P_K(t) + \beta_L P_1(t)$ (2)

$P_3\ '(t) + \sum (\beta_I+\alpha_L)P_3(t) =\sum \alpha_J P_K(t) + \beta_L P_2(t)$ (3)

$P_4\ '(t) + \sum (\beta_I+\alpha_K)P_4(t) =\sum \alpha_J P_K(t) + \beta_K P_2(t)$ (4)

$P_5\ '(t) + \sum (\beta_I+\alpha_K)P_5(t) =\sum \alpha_J P_K(t) + \beta_K P_2(t)$ (5)

$P_5\ '(t) + \sum (\beta_I+\alpha_K)P_6(t) =\sum \alpha_J P_K(t) + \beta_K P_2(t)$ (6)

$P_s\ '(t) + \alpha_s P_s\ (t) =\beta_s P_2\ (t)$ (7)

For steady state availability

By placing d/dt=0, $t \rightarrow \infty$ in the equations, steady state probabilities are as given by,

$P_2=p\ P_1$

$P_3=(\ \beta_L/\alpha_L)\ p\ P_1$

$P_4=p\ P_1$

$P_5=(\ \beta_K/\alpha_K)\ p\ P_1$

$P_s=(\ \beta_s/\alpha_s)\ p\ P_1$ (8)

The full working state probability i.e. by using the normalizing conditions,

$$\sum_{s=0}^{22} P_s=1$$

Using the values of P_2 to P_{23} in terms of P_1into normalizing condition,

$P_1A_1=1$ or $P_1[\ A_1]^{-1}$

Where

$P_1[1 + \beta_I/\alpha_I+ \beta_J/\alpha_J+ q\{1 + \beta_I/\alpha_I+ \beta_J/\alpha_J+ \beta_K/\alpha_K\} + p\ \{1 + \beta_I/\alpha_I+ \beta_J/\alpha_J+ \beta_K/\alpha_K+ \beta_L/\alpha_L\ \} + (\beta_L/\alpha_L) + \{\ \beta_K/\alpha_K+ \beta_J/\alpha_J+ \beta_I/\alpha_I) + (\beta_K/\alpha_K) + (\beta_K/\alpha_K) + (\beta_I/\alpha_I)\ (\beta_L/\alpha_L)\ \} + (\beta_J/\alpha_J).\ (\beta_K/\beta_K) + (\beta_K/\alpha_K).\ (\beta_L/\alpha_L) + (\beta_L/\alpha_L)^2] = 1$

$P_1A_1=1$ or $P_1[\ A_1]^{-1}$ Where $A_1=1$ + repeat the $[1+\ldots\ldots.+()^2\ ]$

The steady state availability of refining subsystem are summation of six operative state probabilities.

$$A_{vst}=\sum_{s=0}^{5} P_s$$

$A_{vst} = P_1[1+p+(\ \beta_L/\alpha_L)\ p +q +(\beta_L/\alpha_L)\ p +(\beta_L/\alpha_L)\ \ (\beta_L/\alpha_L)\ p]$

$A_{vst} =1/G_1[1+p\{1+\ \ \beta_K/\alpha_K+\beta_L/\alpha_L+ \beta_L(\alpha_L+ \beta_K/\alpha_K).\ (\beta_L/\alpha_L)\}+q\}]$ (9)

Where $p = \dfrac{\beta_L}{B_K + \beta_L - \beta_{L.}\, \alpha_J / \alpha_L}$

$q = \dfrac{\beta_K + \beta_L - p\alpha_L}{\alpha_K}$

6. AVAILABILITY ANALYSIS OF REFINING SYSTEM

The performance of refining system depends on the failure and repair rate of the subsystem. Table 1 and Table 2represent the impact of different matches of failure & repair rates. The best possible match of failure & repair rate is selected to increase the system availability.

Table 1: Availability of Filter Subsystem in Refining System

β_I \ α_I	0.050	0.075	0.100	0.125	0.150
0.02	0.288	0.325	0.348	0.363	0.374
0.03	0.245	0.288	0.315	0.334	0.348
0.04	0.214	0.258	0.288	0.309	0.325
0.05	0.189	0.234	0.265	0.288	0.305
0.06	0.170	0.214	0.245	0.269	0.288

Where β_L=0.0020, α_J=0.550, β_K=0.002, α_K=0.050, β_L=0.002, α_L=0.050.

Table 1 and graph in figure 2(a) and 2(b) shows the impact of filter subsystem in the availability analysis of the refining system by using different matches/combinations of repair rate and failure rates. It is found in the observation that for the some familiar values of repair and failure rates of the filter subsystem, as failure rate extends/increases from 0.02 to 0.06, system availability decrease by 40.97%. Similarly as repair rates increase from 0.050 to 0.150,system availability increase by 22.99%.

Table 2 and graph in figure 3(a) and 3(b) shows the impact of clarifier subsystem in the availability of the refining system by using different matches/combinations of repair rate and failure rates. It is found in the observation that, for the few familiar value of repair and failure rates of clarifier subsystem, as failure rate extends/increases from 0.02 to 0.06, system availability decrease by 7.05%. Likewise, as repair rate extends/increases from 0.075 to 0.175, system availability increase by 2.15%. From this analysis, it is observed that for the subsystems K and L, the repair and failure rate does not affect working capacity when it run for long time.

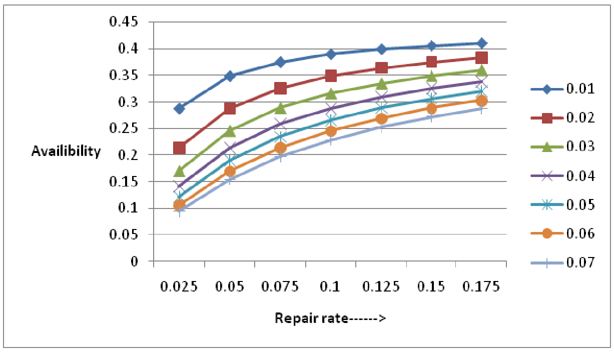

Figure 2(a): Effects of Repair Rate of the Filter Sub-System on the Availability of the Refining System

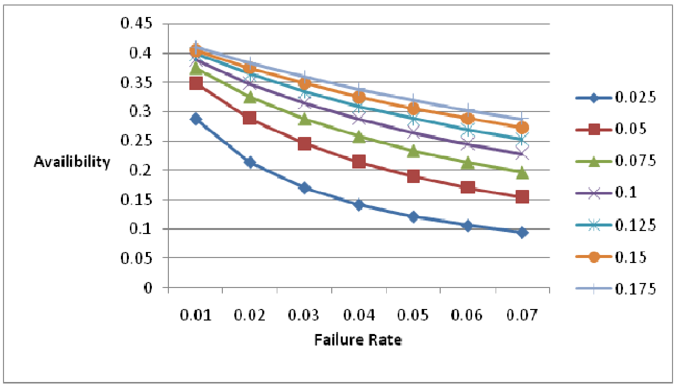

Figure 2(b): Effects of Failure Rate of the Filter Sub-System on the Availability of the Refining System

Table 2: Availability of Clarifier Subsystem in the Refining System

α_J / β_J	**0.075**	**0.100**	**0.125**	**0.15**	**0.175**
0.002	0.638	0.644	0.647	0.650	0.652
0.003	0.626	0.635	0.640	0.644	0.646
0.004	0.614	0.626	0.633	0.638	0.641
0.005	0.603	0.617	0.626	0.632	0.636
0.006	0.593	0.609	0.619	0.626	0.631

where β_A=0.046, α_A=0.101, β_C=0.002, α_C=0.050, β_B=0.002, α_D=0.050

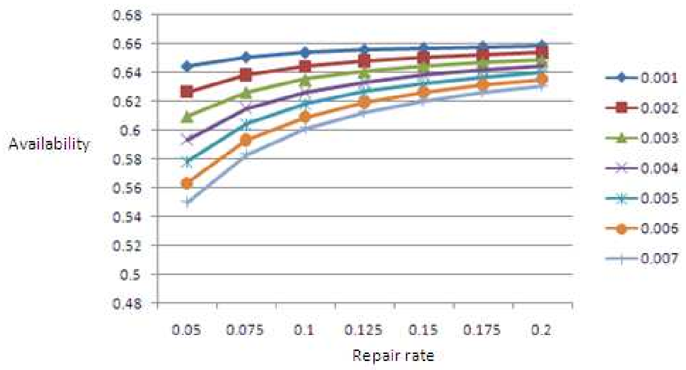

Figure 3(a): Effects of Repair Rate of the Clarifier Sub-System on the Availability of the Refining System

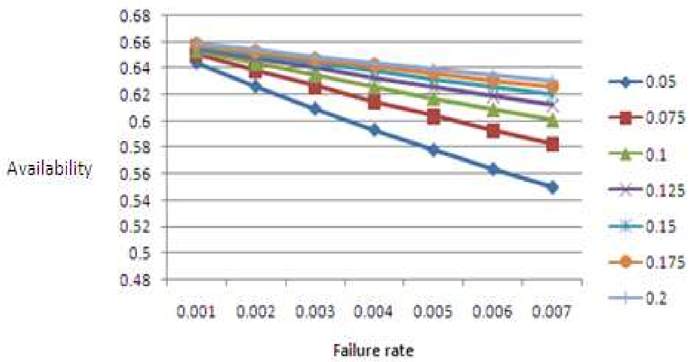

Figure 3(b): Effects of Failure Rate of Clarifier Sub-System on the Availability of the Refining System

7. CONCLUSIONS

It is concluded that for different sub-systems in refining system of sugar plant, the mathematical modelling for availability analysis using Markov Approach can be used effectively. It also shows the relationships between various failure & repair rates in different sub-systems and gives different levels of availability for various combinations/sets of failure and repair rates. The most appropriate maintenance strategies can be decided to get maximum availability of refining system. The most appropriate values of repair and failure rates are shown in Table 3. After these values, only slight increase in availability is noted. So, we select optimum values to get the maximum availability. These findings are shared with engineers and management of concerned sugar industry and are very helpful to them for analysis of availability and in decision making for repair priorities of different subsystems of refining to increase performance of the overall system.

Table 3: Optimal Value of Repair Rate and Failure Rate

Sr. No.	Failure Rates	Repair Rates	Maximum Availability Level
1	$\beta_I = 0.02$	$\alpha_I = 0.150$	0.374
2	$\beta_J = 0.002$	$\alpha_J = 0.175$	0.652

REFERENCES

1. *Dhillon B.S. and Singh C. (1981), 'Engineering Reliability', New Techniques and Applications, John Willey and Sons, New York.*
2. *Arora N. and Kumar D., "Availability analysis of steam and power generation systems in the thermal power plant," Micro-electronics Reliability, vol. 37, no. 5, pp. 795–799, 1997.*
3. *Garg H. and Sharma S.P., "Behavior analysis of synthesis unit in fertilizer plant," International Journal of Quality and Reliability Management, vol. 29, no. 2, pp. 217–232, 2012.*
4. *Aman, Mahna V.K., Khanduja Rajiv, Availability Analysis of Refining System of a Sugar Plant Using Markov Process, International Conference on New Frontiers of Engineering, Science, Management and Humanities (ICNFESMH-2017) at (NITTTR) National Institute of Technical Teachers Training & Research, Chandigarh, India (MHRD, Govt. of India) on 21st May 2017.*
5. *Gupta P., "Markov Modeling and availability analysis of a chemical production system-a case study," in Proceedings of the World Congress on Engineering (WCE '11), pp. 605–610, London, UK, July 2011.*
6. *Gupta P., Lal A. K., Sharma R. K., and Singh J., "Numerical analysis of reliability and availability of the serial processes in butter-oil processing plant," International Journal of Quality and Reliability Management, vol. 22, no. 3, pp. 303–316, 2005.*
7. *Anandaram Burhagohain & Tarini Kumar Dutta., Devaney Chaos and Entropy of the Tridiagonal Markov Chain, International Journal of Applied Mathematics & Statistical Sciences(IJAMSS), Vol.6, no. 2, pp. 19-36*
8. *Kumar S. and Tewari P. C., "Mathematical Modelling and performance optimization of CO2 cooling system of a Fertilizer plant," International Journal of Industrial Engineering Computations, vol. 2, no. 3, pp. 689–698, 2011.*
9. *Kumar R., Sharma A. K., and Tewari P. C., "Markov approach to evaluate the availability simulation model for power generation system in a thermal power plant," International Journal of Industrial Engineering Computations, vol. 3, no. 5, pp. 743–750, 2012.*
10. *Ravi V., Murty B. S. N., and Reddy P. J., "Non equilibrium simulated annealing-algorithm applied to reliability optimization of complex systems," IEEE Transactions on Reliability, vol. 46, no.2, pp. 233–239, 1997.*

11. *M. Manikandan, G. Thiyagarajan, J. Bhuvaneswari & N. K. Prabhakaran, Wet and Dry Spell Analysis for Agricultural Crop Planning Using Markov Chain Probability Model at Bhavanisagar, vol. 7, no.1, pp. 11-22, 2017.*

12. *Sharma S.P. and Vishwakarma Y., "Application of Markov Process in Performance Analysis of Feeding System of Sugar Industry" Research article, Hindawi publishing corporation, journal of industrial mathematics, volume 2014.*

13. *Ravi V., Reddy P. J., and Zimmermann H.-J., "Fuzzy global optimization of complex system reliability," IEEE Transactions on Fuzzy Systems, vol. 8, no. 3, pp. 241–248, 2000.*

14. *Kumar R., "Availability analysis of thermal power plant boiler air circulation system using Markov approach," Decision Science Letters, vol. 3, no. 1, pp. 65–72, 2014.*